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LABORATORY PERFORMANCE DURING ACUTE INTOXICATION AND HANGOVER.(U)
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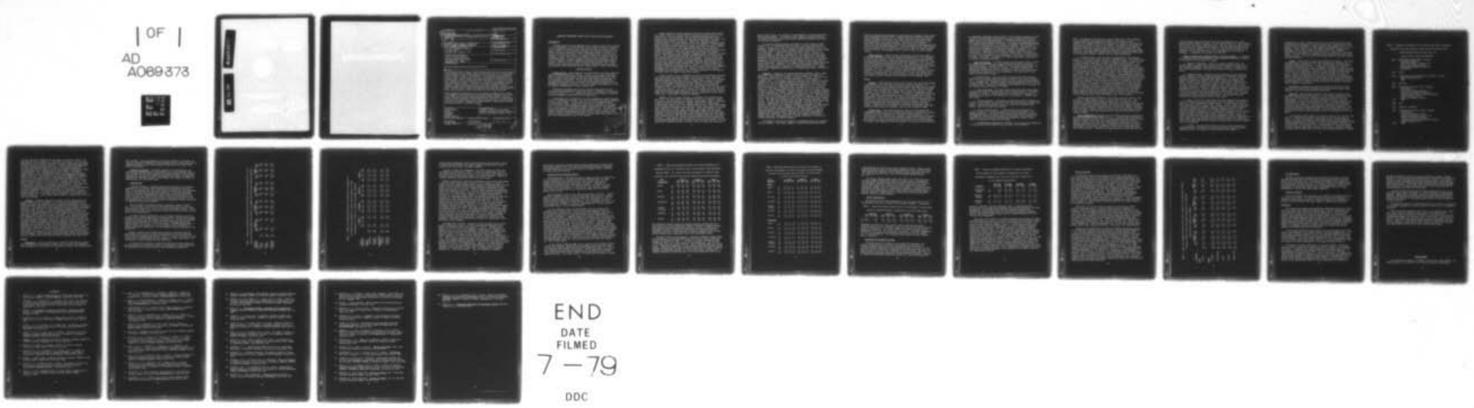

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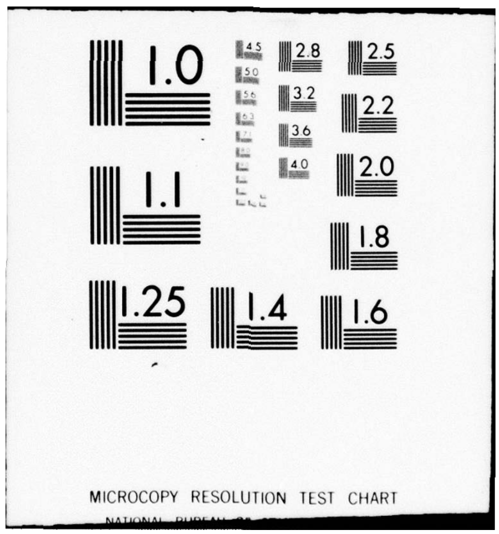
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16. Abstract

Eleven private pilots (7 men and 4 women) were recruited and trained on the Multiple Task Performance Battery (MTPB), static and dynamic tracking of a localizer/glide slope instrument, a speech intelligibility test (single words with a background of aircraft noise), and use of the Intoxilyzer. The experiment comprised four test sessions (vodka, bourbon, placebo, and control sessions) held at weekly intervals. Sessions began at about 1700 and continued through midnight to about 1100 the next day. Subjects were tested in groups of 3 or 4 and were not told whether they were drinking alcohol or placebo. The ordering of sessions was approximately counterbalanced. Subjects were given all tests in the evening (before and after a monitored dinner), drank prepared beverages from 2030 to midnight, and were tested again. Subjects slept 4-5 hours, were awakened around 0700, fed, and performed all tasks again, beginning at 0800 (8 hours after they had finished drinking).

Results showed clear deleterious effects of alcohol on the MTPB and the tracking tasks immediately following drinking. During the morning (hangover) tests, scores on the MTPB and on the static and dynamic tracking tasks showed small circadian effects (scores were better) without impairment due to the alcohol. Speech perception scores were unaffected by alcohol; scores were always best in the evening and poorest in the morning. There were no congener effects. These results thus offer no evidence contrary to the "8-hour rule."

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LABORATORY PERFORMANCE DURING ACUTE INTOXICATION AND HANGOVER

Introduction.

Although Federal Aviation Regulation 91.11 states in part that no one may act as a crewmember of a civil aircraft within 8 hours after the consumption of any alcoholic beverage or while under the influence of alcohol, toxicological studies of pilot fatalities indicate that inflight performance sometimes occurs under conditions in which detectable amounts of alcohol are present in the blood of pilots; still other flights occur during so-called "hangover" stages. While there is sufficient evidence to indicate that the performance effects of acute alcohol intoxication are detrimental, there is little information available regarding aviation-related performance during hangover. Moreover, there is conflicting evidence available that alcohol which contains significant amounts of congener substances may have longer lasting and/or more pronounced effects on some aspects of human functioning.

PREVIOUS STUDIES

General Effects. Most studies of the acute effects of alcohol ingestion report performance decrements (48,49). Results are not always consistent, however, unless dosages produce relatively high blood alcohol levels (BAL) (say 0.50 percent and higher) and even then some tasks or measures may not show decrements (8,15,30,43). On the other hand, relatively low doses (producing blood alcohol levels around 0.20-0.30 percent) sometimes effect performance decrements (12,16,33). Thus, the ability requirements of a task are important determinants of alcohol effects (29).

Performance impairment due to acute alcohol intoxication has been specifically demonstrated for flying tasks, both in simulators (1,19,20) and in actual aircraft (4). The studies all suggest that performance decrements can be anticipated at BAL levels below 50 mg percent.

Considerably less information is available regarding so-called hangover effects on performance and only a few studies have been specifically designed to assess those effects. Studies which were not so designed but which reported measures taken several hours after drinking include two by Ekman et al. (13,14) in which performance (memory and arithmetic) was assessed 5 hours after ingestion of whiskey; another by Collins et al. (9) which reported tracking performance scores 10 hours after drinking vodka. None of these daytime studies yielded detrimental effects past 4 hours (the memory test showed no effect of alcohol at any point), and mean peak blood alcohol levels were over 70 mg percent in each of the studies.

Studies designed to assess hangover effects have yielded mixed results. Thus Takala, Siro, and Toivainen (46) gave subjects brandy and beer in the evening (over a 2½-hour period), which yielded postdrinking mean blood alcohol levels of 124 mg percent for beer and 152 mg percent for brandy, and compared those subjects to controls. Significant impairment occurred following alcohol in all performance scores (tests measured perceptual speed, space, dexterity, and number and took 3 hours to complete). During hangover sessions (12½ hours after drinking), brandy scores were identical to control scores while beer scores, when compared with scores made by controls, yielded significantly poorer results for space tests and significantly better results for dexterity. Karvinen, Miettinen, and Ahlman (25) assessed physical performance (bicycle ergometer, handgrip tension, backlift, and jump tests). Their subjects drank ethanol-fortified cognac in the evening and were tested around 12 hours later the next morning. Only the bicycle test showed effects of hangover (less workload performed). Ideström and Cadenius (23) used four doses of alcohol in a grape drink and examined effects on reaction time, tapping speed, coordination, critical fusion frequency (CFF), standing steadiness, and cancellation of letters. The highest dose (mean peak BAL of about 70 mg percent) had the most consistent effects and impaired performance on all tests except CFF. However, 2 hours after drinking, performance was approximately the same as before drinking; the next morning (13 hours later) no alcohol effects were evident.

Myrsten, Kelley, Neri, and Rydberg (37) served three different beverages (aqua vitae, beer, and cognac) during a 1½-hour evening meal, achieving a mean peak blood alcohol level of about 120 mg percent. Their tests included standing steadiness (eyes open and eyes closed), hand steadiness, reaction time, a timed sequence-identification test (Spokes), the F test (verbal, inductive, numerical, and spatial factors), and number identification (correction test). Data were based on 15 subjects ages 31-54, who were used as their own controls. All 10 test scores except simple reaction time were significantly poorer during acute intoxication. Twelve hours after drinking ended only two tests showed decrements, *viz* hand steadiness and the spatial factor test. Morning BALs averaged 4 mg percent.

Seppälä, Leino, Linnoila, Huttunen, and Ylikahri (42) divided 40 men, ages 18-25, into equal groups of controls, alcohol only, alcohol + sugar I (fructose or glucose given in the evening), and alcohol + sugar II (fructose or glucose given in the morning). Subjects fasted for 10 hours before drinking ethyl alcohol for 3 hours between 1800 and 2100. Peak blood alcohol levels exceeded 200 mg percent and were still above 50 mg percent 10-14 hours later (tests given at 0800, 1000, and 1200). Tests were related to automobile driving and involved choice reaction time (lights and foot pedal responses, sound and hand responses), coordination (eye-hand and multilimb; essentially a type of tracking task using a steering wheel and a foot pedal), and an attention test (two central and two peripheral dials with revolving pointers). Since subjects were not equated on the tests (all conducted the next morning) although all were trained, results are a bit unclear. The only significant difference between the control and the alcohol-only group was in choice reaction time. The addition of sugar appeared to impair coordinative skills during hangover. The attention test yielded no group differences. The authors reported no correlation between impaired performance and subjective severity of hangover.

Two aviation-oriented studies have sought to assess hangover effects. Carroll et al. (6) used pilots ages 23-31 and a task that involved both tracking a moving point source and canceling lights displayed in the visual periphery. Subjects were given a premixed orange juice/alcohol mixture, drank it at home within a 1-hour period and were tested 10 hours later in an altitude chamber. Conditions included three dose levels, a placebo, and three altitudes (15 minutes of performance). No statistically significant detrimental effects were obtained. More recently, Dowd et al. (11) tested subjects in the morning (at which time mean blood alcohol levels exceeded 20 mg percent), 9 hours after drinking either bourbon or vodka (there was no control condition). Subjects had to adjust a pitch control during centripetal acceleration in the laboratory. No significant deleterious effects were obtained and there were no congener vs. noncongener differences. However, neither study demonstrated sensitivity of the performance tests to alcohol to begin with.

<u>Congeners</u>. Congeners, the various substances (methanol, esters, aldahydes, etc.) other than ethyl alcohol found in alcoholic beverages, are anecdotally associated with hangovers or hangover severity. Vodka is so low in congener content that it is often referred to as "noncongener" or "congener free." Less frequent subjective symptoms during hangover have been reported for vodka as compared with whiskey by Damrau and Liddy (10) and by Brusch et al. (5), but their experimental approaches make the results less than convincing (e.g., Damrau and Liddy (10) administered only 2 ounces of alcohol to nondrinkers or moderate social drinkers and obtained what they referred to as an "unexpected" relatively high percentage of hangover effects). A study by Chapman (7), however, compared bourbon- and vodka-induced hangovers (9 hours after drinking) in 60 subjects and reported 20 of 30 subjects given bourbon and 13 of 30 given vodka as having definite hangover. Only one of the latter group rated the hangover as severe while 10 of the group given bourbon did so. Mean peak blood alcohol levels for these findings were about 125 mg percent. At lower doses (yielding mean peak BALs of 65 mg percent and 110 mg percent), symptoms were rare for both beverages. Similarly, (i) Hill, Schroeder, and Collins (21) reported no differences between 10 subjects given bourbon and 10 given vodka in headache or hangover ratings either 8 or 24 hours after drinking (mean peak BALs were near 100 mg percent) and (ii) Prokop and Machata (38) obtained significantly more reports of hangover symptoms from 30 subjects given vodka plus fusel alcohol supplements as compared with vodka alone; their peak BALs were around 125 mg percent. Perhaps relatively large quantities of congener substances are required to produce differences in hangover symptoms.

The possible influences of congeners on performance have also received minimal treatment. Two studies suggest no consistent differences between vodka and congener-type beverages for several types of behavioral tests during acute intoxication periods (7,50). Another study (26) reported no vodka vs. bourbon differences on reaction time (simple and complex) but poorer mirror drawing performance after bourbon than after water; no performance effects were significant 5 hours after drinking. Some studies have reported significant response differences between vodka and congener beverages when the latter have been "congener fortified." Thus, differences using "super-bourbon" have been reported for risk taking (26,47) using 4 times the normal congener levels and for EEG and nystagmus (34,35) using 32 times the normal congener content.

Smoking Effects. Several previous studies have specifically sought to define the interactive effects of smoking and drinking (i.e., the interaction of nicotine and alcohol). Several studies (2,28,36) involved only subjects who were smokers and tested them under smoking and deprived conditions. Some performance differences are obtained under these conditions, e.g., reaction time and arithmetic performance were better with smoking than without in these subjects during acute intoxication, but the opposite relationship held 11 or more hours later (2). A daytime study (31) which compared smokers and nonsmokers on a choice reaction time task suggested some differences favoring smokers in "decision time" but no differences in "motor time" during acute intoxication following low and moderate doses of alcohol (maximum BALs were 0.012 percent for the low dose and 0.065 percent for the moderate dose).

Method.

Subjects. Eleven general aviation pilots (seven men, four women) ranging in age from 22 to 55 years (mean, 39.6 years) served as subjects. All represented themselves as light-to-moderate drinkers who would have no trouble handling five or so ordinary drinks in an evening. Their flying time ranged from 160 hours to 20,000 hours (overall mean = 4,383; mean for men = 6,664, for women = 390) and they were variously certificated as commercial pilots, flight instructors, and private pilots. The subjects volunteered to spend one night a week for several consecutive weeks in the laboratory from 1700 to approximately 1200 the next day. All subjects were administered a placebo, a bourbon, and a vodka mixture over the period of test weeks. Subjects did not know which mixture they were drinking on any given night and the order of mixture presentation was counterbalanced as much as possible among the subjects. Subjects were not allowed to have coffee or beverages containing caffeine between dinner and breakfast, but they were allowed to smoke.

Tracking Task. Each subject performed singly on a two-dimensional compensatory tracking task for 5 minutes during angular acceleration (dynamic condition) and for 5 minutes while stationary (static condition). The tracking task system consisted of an aircraft localizer/glide slope indicator and a joystick. The vertical and horizontal needles of the indicator were deflected by individual sinusoidal forcing functions with 15-second periods. The subject was instructed to keep the needles in the center or null positions by compensatory movements of the joystick. The integrated tracking error for localizer and glide slope deviation was recorded on separate channels of a Beckman Type T electroencephalograph. An enclosed Stille-Werner rotation device provided the angular stimulation. The rotation was programed, by use of a Wavetek signal generator, to provide a triangular waveform stimulus with a period of 48 seconds and a peak velocity of $\pm 90^{o}$/sec. The room was in total darkness throughout the testing session with the exception of a light source that was focused on the tracking instrument to provide a 1.0 fL of illumination. Immediately after tracking, subjects rated their effort (0-25 percent, 26-50 percent, 51-75 percent, 76-90 percent, 91-100 percent) and gave a self-appraisal of their performance (1-very poor, 2-below average, 3-average, 4-very good, 5-excellent) on 5-point rating scales, separately for static and dynamic conditions.

Complex Performance. The CAMI Multiple Task Performance Battery (MTPB) was used to provide measures of complex workload performance requiring time-sharing skills. The MTPB consisted of five subject testing panels and associated programing and scoring circuitry. The panels contained the displays and response controls for six different tasks, each of which could be presented in isolation or in any combination. The tasks used in this study are described as follows:

1. Warning lights. This was a choice reaction time task involving monitoring of five green lights (normally on) and five red lights (normally off). The subject was instructed to push the button under the light whenever a light changed state. Response time was recorded separately for the red and the green lights. Signals not responded to were removed after 15 seconds and the response time was scored as 15 seconds.

2. Meter monitoring. This task involved monitoring four meters whose pointers were moving at random around a mean vertical position. The subject responded to a shift in the mean position of the pointer by throwing the associated lever switch in the direction of the deflection. Response times were scored.

3. Mental arithmetic. The subject was required to add two numbers and subtract a third number from the sum of the first two without using paper and pencil. Answers were recorded by means of a push-button response panel. Response time and accuracy were assessed.

4. Pattern identification. A standard pattern was displayed on a 6x6-cell screen for 5 seconds followed by 2-second presentations of two comparison patterns. The subject then decided if one, neither, or both of the comparison patterns were the same as the standard (first) pattern and indicated his or her answer by pressing the appropriate response button. Speed of response and accuracy were recorded.

5. Two-dimensional compensatory tracking. The tracking task display was an oscilloscope screen mounted in the top center of the subject's

panel. The target on the screen was a dot of light about 1 mm in diameter. A varying amplitude disturbance was imparted to the target in each dimension; the subject attempted to counteract the disturbance by using the control stick to keep the dot at the center of the screen (as defined by two crosshairs scribed on the face of the screen). Performance was scored by analog circuitry that integrated absolute error and error squared for each dimension. The error-squared measure was converted to root-mean-square (RMS) errors and vector RMS error measures derived from horizontal and vertical RMS error scores were used as a single index of tracking performance.

6. Problem solving. Each test panel is equipped with five response buttons, a "task active" light, and three "feedback" lights. Each subject had to discover a correct sequence in which to press the buttons in order to turn on a blue feedback light that signified the problem had been solved. The problem was solved by following a trial-and-error search procedure, using error information provided by the red feedback light. Whenever a button was pushed that was not in the correct sequence, the red feedback light was turned on and the part of the sequence that the subject had already discovered had to be reentered before the search could continue. When a problem was solved, a lapse of 20 seconds occurred, following which the same problem was presented a second time. Thus, the subject had to remember the correct sequence and could not (efficiently) solve all problems in a trial-and-error manner without paying attention to which buttons were correct and which were incorrect for a given phase of the solution. After entering the solution a second time and after another lapse of 20 seconds, a new problem was presented. Several measures comprised scores on this task: (a) speed of solution of the first presentation of a problem, (b) speed of reentering the solution in the confirmation phase, (c) the proportion of redundant responses made during the solution phase (responses made when information already acquired should make the subject aware that the response being made is not correct), and (d) proportion of error responses made on the confirmation entry of the solution.

Subjects performed the MTPB for a full hour of each test session, with the array of tasks changing in each 15-minute block of that hour. The monitoring of lights and of meters was required in each block; to these continuous tasks were added arithmetic plus tracking, arithmetic plus problem solving, patterns plus problem solving, and patterns plus tracking, respectively, in the successive 15-minute blocks of each test session. Following MTPB performance, subjects rated their effort and their performance for each of the six tasks on the same rating scales as those used after static and dynamic tracking.

Speech Comprehension. Equated lists of 50 words each were constructed on tape from the CHABA Modified Rhyme Test (22). An Advent Model 202 cassette recorder presented the taped voice of a man speaking each word against a background of aircraft noise over an Acoustic Research 3 speaker, which was centrally located in the test room. Preliminary testing during a series of familiarization trials for the subjects established the sound levels which would yield a 50-60 percent correct score on each test (75 dBA for speech and 77 dBA for noise). Response sheets contained six printed words for each of the 50 spoken words on each tape; all of the alternatives for a given spoken word were similar in sound. For each spoken word (e.g., "pay") subjects had to circle one of six alternatives (e.g., pay, day, gay, say, may, way) as the word that they thought had been spoken. The lists were presented in the same order for all subjects (i.e., List A was used as the first test for all subjects, List B as the second test, etc.) irrespective of the drinking condition. A different list was used for each test.

Degree of Drunkenness, Hangover, Mood, and Anxiety Ratings. In addition to ratings of effort and performance on the tracking and MTPB tasks, subjects also provided four other types of ratings.

1. Degree of Drunkenness. During the interval between static and dynamic tracking, subjects were asked to rate how "drunk" they felt (not at all, slightly, moderately, more than moderately, extremely). Ratings were obtained during midnight and morning test sessions and were scored on a 0-4 scale.

2. Hangover Ratings. Immediately after drinking and after breakfast, subjects completed a 20-item hangover questionnaire developed by Gunn (18) and also answered four additional items added by us. The first 23 items comprised a checklist of symptoms (feel like throwing up, stomach ache, hungry, headache, loose bowels, tight bowels, muscle aches, shaking, dizzy, feel hot, feel confused, eyes burn, backache, nose runs, nervous, tired, dry mouth, feel sad or depressed, ringing in ears, hurts to move, thirsty, nauseated, heartburn) to which the subjects responded according to one of four categories (not at all, a little, some, quite a bit). Items were scored on a 0-3 scale and a mean score was calculated for each subject. The final item ("rate your hangover") was scored similarly and constituted both a separate score and part of the overall hangover rating. The overall rating was obtained by a simple summation of the 24 item scores.

3. Mood. A list of 15 items from the 80-item composite Mood Adjective Check List (CMACL) developed by Malmstrom (32) was devised on the basis of some of our previous work with alcohol effects. The list (mMACL) consisted of 15 adjectives (active, drowsy, dull, sluggish, tired, sleepy, bored, lazy, leisurely, nonchalant, energetic, vigorous, fatigued, happy, and annoyed) which the subjects rated on a 9-point scale ranging from "not at all" descriptive through "moderately," to "definitely" descriptive of the subject's current feelings. Five mood scores were calculated, based on the sum of scores for specified items, viz, fatigue, nonchalance, vigor, sleepy, and affect tone; the first four scores were determined according to Malmstrom (32) while "affect tone" was derived from the two final items on our check list. The list was administered before drinking, after drinking, and after breakfast under all conditions.

4. Anxiety. The State-Trait Anxiety Inventory (STAI) developed by Spielberger and his associates (45) was used to assess anxiety (or psychological arousal). One section of the STAI measures the subject's

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predisposition ("trait") toward anxiety or how the subject generally feels; the other section measures his current anxiety level ("state") or how the subject feels at that moment. Each section has 20 statements (e.g., "I tire quickly," "I feel content") and four response categories ("almost never, sometimes, often, almost always" for trait; "not at all, somewhat, moderately so, very much so" for state) scored on a scale of 1-4 points and summed. The trait section was completed by all subjects during one of the practice periods. The state section was completed before and after drinking and after breakfast.

Alcohol. Three kinds of drinks were provided the subjects. Each drink contained either 100-proof Smirnoff vodka (noncongener), 100-proof Old Fitzgerald bourbon (congener), or a trace of rum extract and food coloring (placebo), each mixed with 7-Up. A common pool of vodka and another of bourbon were initially established in separate containers to insure beverage uniformity for all subjects. The amount of the alcoholic beverage given was 3.25 ml per kg of body weight, which was equally divided into four large drinks. Drinks contained two parts of 7-Up for each part of alcohol; placebo drinks were equivalent in volume but contained only 7-Up diluted by water in place of the alcohol plus a few drops of rum extract and coloring. The order of administering the alcohol and placebo was randomized as much as possible among the 11 subjects who were told that they would be receiving "some" alcohol in every drink.

Breathalyzer readings were taken from an Omicron Intoxilyzer before drinking began (about 1945), immediately after the drinking period ended (midnight), and the following morning (about 0800).

Procedure. Subjects were exposed to three 3-hour training sessions following a 45-minute orientation period. The training included all tasks which the subjects would be required to perform (including use of the breathalyzer). The 9 hours of training were spaced across 3 days and approximately 7½ hours were devoted to the MTPB. The static tracking task was performed six times and the dynamic task five times during training. Training in the speech task involved first an exposure to 10 minutes of continuous speech, following which subjects had to write responses to four questions regarding the speech material, then three additional training periods each of which involved exposure to one of the prepared lists of 50 words.

The experiment proper began the next week at 1700 on each test day (see Table 1). Subjects were tested in two groups of four and one group of three. Test days were Monday evening through Tuesday morning, Wednesday evening through Thursday morning, and Friday evening through Saturday morning. Following attachment of electrodes to record eye movements, completion of STAI and mMACL, a breathalyzer test, and performance of static and dynamic tracking, subjects were taken to dinner. After dinner, subjects performed the speech and the MTPB tasks until 2000 when they began drinking. Drinking

TABLE 1. Schedule of procedures for the placebo and alcohol conditions. During the sleep control week, subjects drank the placebo drink, completed questionnaires around 2300, and were in bed no later than midnight.

1700	Predrinking session (PRE): Evening Electrode attachment Static and dynamic tracking tasks State-Trait Anxiety Inventory Modified Mood Adjective Check List Breathalyzer
1800	Dinner
1845	Continuation of predrinking session (PRE): Evening Speech Perception Test MTPB
2000	Drinking
0000	Postdrinking session I (PI): Midnight Breathalyzer State-Trait Anxiety Inventory Modified Mood Adjective Check List Hangover Questionnaire Drunkenness Rating Speech Perception Test Static and dynamic tracking
0115	MTPB
0230	Bed
0700	Awakened: Breakfast
0730	Postdrinking session II (PII): Morning Breathalyzer Static and dynamic tracking Modified Mood Adjective Check List State-Trait Anxiety Inventory Hangover Questionnaire Drunkenness Rating Speech Perception Test
0830	MTPB

time was from 2000 to midnight for two subjects and 2015 to 0015 for the remaining one or two subjects in each group. Each subject had four large drinks with 1 hour to finish each drink. Subjects played ping pong, cards, and table hockey and watched television to create a party-like atmosphere. The first post-alcohol session (PI) was run at midnight immediately following drinking with subjects rating their degree of drunkenness, taking the breathalyzer test, and completing the STAI, mMACL, and hangover questionnaires. After completing the speech, tracking, and MTPB tests, subjects were put to bed around 0230 in the Civil Aeromedical Institute's clinic facilities. Two subjects in each group were awakened at 0700 (the other one or two subjects at 0715) for breakfast and began their final testing session (PII) at 0730 (or at 0745). Subjects returned for 3 more weeks (totaling 4 weeks) on the same day of the week for retesting. The "sleep control" week was the last week of the experiment. The differences in this week in relation to the preceding weeks were the absence of alcoholic beverages (subjects drank the same mixture as the placebo drinks), no evening requirement for MTPB performance, and elimination of the PI session at midnight. The absence of the latter permitted the assessment of possible effects due to the abbreviated sleep periods in the placebo and alcohol conditions. In this sleep control condition, subjects were in bed no later than midnight.

Analyses. Initially, analyses of variance between sleep control and placebo conditions were performed on all scores for the predrinking and hangover sessions (two exceptions were the Hangover Questionnaire and the Drunkenness Rating which were given only during the intoxication and hangover sessions). Only two measures (both related to feelings) yielded significant differences, *viz*, STAI ($p < .05$) and the Hangover Questionnaire ($p < .01$). For these latter two measures (both of which would likely be affected by sleep loss), subsequent analyses of variance comprised scores from all four conditions (control, placebo, bourbon, and vodka). All remaining measures were subjected to analyses of variance with the control condition deleted. It is perhaps worth noting that for static tracking, dynamic tracking, and nystagmus ratings, performance scores were numerically better in the placebo condition for both predrinking and morning sessions; speech perception performance was numerically higher in the predrinking session of the placebo condition but lower than the sleep control condition for hangover scores. Significant F ratios were treated first by simple effects tests and then by Tukey's HSD test (27). In the case of missing data for any measure (due to intoxication, two subjects on one occasion each were unable to perform any test at midnight and both declined to perform dynamic tracking the following morning), missing cells were filled according to Snedecor and Cochran (44).

Results.

Breathalyzer. Only one subject gave a positive breath-alcohol reading after arriving at the laboratory (a woman, first session of the experiment, took two glasses of wine earlier that afternoon at a party; she received vodka that evening). The mean breathalyzer levels were identical for bourbon and vodka (0.093 percent) immediately after drinking and were almost identical the following morning, 8 hours after drinking (0.007 percent for vodka; 0.005 percent for bourbon).

Inability to Perform. Two subjects became ill from drinking on one occasion each and were unable to participate in any of the midnight tests on that occasion; they both also declined to attempt performance at the dynamic tracking task (rotation) the morning following their illness, although they completed all other morning tasks. Both subjects were women; one became ill after bourbon, the other after vodka.

Tracking Task.

Tracking Performance. Separate analyses of horizontal and of vertical components of the tracking tasks yielded identical statistical findings; thus, for presentation here, the vector sums of tracking error were calculated (Table 2) and submitted to statistical treatment. The static and dynamic tracking conditions showed generally similar results; *viz*, morning (PII) scores for all three conditions were better (less error) than evening (Pre) scores, midnight (PI) scores for both alcohol groups had increases in error, but midnight scores for the placebo group were intermediate between those from the predrinking and morning sessions.

Overall analyses of variance yielded a significant sessions effect ($p < .01$) for static tracking scores, and significant sessions, conditions, and interaction effects ($p < .001$ in all cases) for dynamic tracking. (These results were the same as those obtained for horizontal scores and for vertical scores tested individually.)

For static tracking performance, only the bourbon condition during the midnight session showed significant individual effects; specifically, bourbon produced more errors than the placebo at midnight ($p < .01$) and that midnight session had significantly more errors than both the predrinking and the morning bourbon sessions ($p < .01$ in both cases). Although vodka produced similar trends, the increase in error at midnight was not sufficient to produce statistical significance. No other group or session differences were significant.

Dynamic tracking scores yielded more consistent individual findings. Specifically, both bourbon and vodka produced more error at midnight than during evening and morning sessions ($p < .001$ in all cases), and both resulted in more error at midnight than did the placebo ($p < .001$ in both cases). No other group or session differences were significant.

To insure that the failure to obtain any significant effects during the morning (hangover) sessions was not due to the presence of strong effects for the midnight session, separate analyses were conducted by using first

TABLE 2. Means and standard deviations for the vector sums of tracking error in the static and dynamic modes and ratings of nystagmus obtained during dynamic tracking.

Tracking Measure		Control			Placebo			Bourbon			Vodka		
		Pre	PI	PII	Pre	PI	PII	Pre	PI	PII	Pre	PI	PII
Static	M	165	-	151	160	158	146	159	205	156	161	188	154
Error	SD	52	-	47	38	47	42	50	93	51	37	70	48
Dynamic	M	191	-	176	188	184	168	189	279	174	181	298	169
Error	SD	63	-	52	45	49	41	67	100	50	44	92	54
Nystagmus	M	1.51	-	1.52	1.26	1.05	1.32	1.52	2.89	1.55	1.49	2.57	1.70
Rating	SD	1.52	-	1.32	1.32	1.41	1.61	1.53	1.89	1.43	1.48	1.81	1.64

TABLE 3. Means and standard deviations for ratings by the subjects of the effort they expended (1-5 scale) and the quality of their performance (1-5 scale) for static and dynamic tracking.

Rating Condition		Control Pre	Control PI	Control PII	Placebo Pre	Placebo PI	Placebo PII	Bourbon Pre	Bourbon PI	Bourbon PII	Vodka Pre	Vodka PI	Vodka PII
Effort													
Static Tracking	M	4.9	-	4.9	4.8	4.9	4.8	4.8	4.9	4.7	4.7	4.7	4.6
	SD	0.3	-	0.3	0.4	0.3	0.4	0.4	0.3	0.7	0.5	0.6	0.5
Dynamic Tracking	M	4.9	-	4.9	4.9	4.9	4.8	4.9	4.9	4.7	4.9	4.7	4.7
	SD	0.3	-	0.3	0.3	0.3	0.4	0.3	0.3	0.6	0.3	0.6	0.5
Performance													
Static Tracking	M	3.5	-	3.6	3.4	3.5	3.4	3.7	2.8	2.9	3.0	2.6	3.1
	SD	0.8	-	0.8	0.7	0.7	0.7	0.8	0.9	0.8	1.1	0.7	0.5
Dynamic Tracking	M	3.3	-	3.6	3.2	3.1	3.3	3.6	2.4	3.1	3.5	1.9	3.1
	SD	0.9	-	0.7	0.8	0.5	0.7	0.9	0.8	0.7	1.2	0.9	0.9

evening-morning difference scores and then morning-only performance scores. No significant differences were obtained among the conditions by either analysis for either static or dynamic tracking.

Ratings of Effort and Performance. The mean ratings for effort and performance are presented in Table 3. Effort was consistently rated at a very high level (no less than a mean of 4.6 on a 5-point scale) across all sessions and conditions for both static and dynamic tracking. Analyses of variance yielded no significant effects for this measure.

Subjects consistently rated their performance at both static and dynamic tracking as better than average (a mean of 3.0 or higher on a 5-point scale) during all sessions except those conducted at midnight which involved alcohol (1.9-2.8 scores) and the morning session following bourbon for static tracking only (2.9 score). Overall analyses of variance yielded a significant conditions effect ($\underline{p} < .05$) for static tracking and significant effects for both sessions ($\underline{p} < .001$) and the interaction of conditions and sessions ($\underline{p} < .05$) for dynamic tracking. The static tracking effect occurred in the midnight session where the performance rating for vodka was significantly lower than placebo ($\underline{p} < .05$) and the bourbon ratings at midnight and in the morning were significantly lower ($\underline{p} < .01$ and .05, respectively) than the predrinking session (in this case, the predrinking value was higher than usual). Similarly, for dynamic tracking, vodka performance ratings were significantly ($\underline{p} < .01$) lower than placebo ratings at midnight and were also lower than both the vodka predrinking ($\underline{p} < .001$) and morning ratings ($\underline{p} < .01$). The bourbon performance rating at midnight was also lower ($\underline{p} < .01$) than the predrinking rating. Thus, although they rated their effort at consistently high levels, the subjects' ratings of their performance indicate an awareness of a decline at midnight after drinking alcohol (which parallels their tracking error scores) but also indicates a (statistically insignificant) tendency to underestimate their performance during hangover.

Nystagmus While Tracking. Ratings of ocular nystagmic output during dynamic tracking were made by a trained rater without knowledge of the subject or condition; these values appear in Table 2. Ratings ranged between 1.0-1.7 on a 0-4 scale (judged on a combination of frequency and amplitude) for all sessions and conditions except those at midnight which involved alcohol (2.57 and 2.89 for vodka and bourbon, respectively). Overall analyses of variance yielded significant effects for sessions ($\underline{p} < .001$), conditions ($\underline{p} < .001$), and the sessions by conditions interaction ($\underline{p} < .01$). These overall significant effects were accounted for by the higher ratings of nystagmic output at midnight for both bourbon and vodka than were obtained during both the predrinking ($\underline{p} < .001$ and .01, respectively) and the morning ($\underline{p} < .001$ and .05, respectively) sessions for the two alcoholic beverages, and by the significantly higher midnight ratings following ingestion of both bourbon and vodka than that obtained for the placebo condition ($\underline{p} < .001$ in both cases). Thus, the ingestion of alcohol significantly increased nystagmus during dynamic tracking, as has been noted in previous studies (9,16), but there was no difference between the bourbon and vodka conditions in the average ratings of nystagmus either at midnight or the morning after drinking.

Multiple Task Performance Battery.

MTPB Performance. For MTPB performance, comparison data for placebo and control conditions were available only for the morning scores (no sleep control predrinking tests were conducted, and of course there were no midnight tests scheduled for sleep control sessions). There was no significant difference between the morning scores on the MTPB for placebo and sleep control conditions ($t = 0.81$) and, in fact, the mean composite score for the placebo condition was numerically higher than that of the control (527 vs. 525).

Mean performance scores for the MTPB are presented in Table 4. Overall analyses of variance on each of the six individual tasks and on the overall composite yielded significant sessions effects for all scores ($p < .001$ for all but problem solving and meters where $p < .05$), significant condition effects only for tracking ($p < .001$) and the overall composite ($p < .05$), and three significant sessions x conditions interactions ($p < .05$ for tracking and patterns and $p < .01$ for warning lights).

For the individual tasks, the significant F ratios for meters and arithmetic were largely overall effects (individual comparisons did not yield significant results) due to consistently lower midnight scores across all groups for meters and to consistently higher scores during morning sessions for arithmetic. Somewhat similarly, circadian effects were evident in the problem-solving task with midnight scores consistently the poorest and morning scores consistently the best; however, in only one case were these differences significant, viz, for the bourbon condition, midnight scores were significantly lower ($p < .05$) than morning scores. Some more striking effects were obtained for the remaining three tasks. Specifically, the vodka midnight session for patterns and both the vodka and bourbon midnight sessions for tracking and warning lights differed significantly (performance was poorer) from their respective predrinking and morning scores ($p < .001$ in all cases). Also vodka midnight scores for patterns were significantly lower than those for both placebo ($p < .001$) and bourbon ($p < .05$), bourbon midnight scores for warning lights were lower ($p < .001$) than those for placebo, and both bourbon and vodka midnight scores for tracking were poorer than those for placebo ($p < .001$ in both cases).

For the overall composite MTPB scores, clear-cut and consistent alcohol effects were obtained. Specifically, the midnight scores for both bourbon and vodka were significantly lower than both predrinking scores ($p < .01$ and .001, respectively) and morning scores ($p < .001$ in both cases). Moreover, both bourbon and vodka scores at midnight were significantly poorer than placebo scores ($p < .01$ in both cases). To insure that the failure to obtain

TABLE 4. Means and standard deviations for overall performance and performance on the six individual tasks of the Multiple Task Performance Battery (MTPB). All scores have been transformed to standard format (mean=500, S.D.=100) with higher scores representing better performance.

MTPB Performance		Placebo Pre	Placebo PI	Placebo PII	Bourbon Pre	Bourbon PI	Bourbon PII	Vodka Pre	Vodka PI	Vodka PII
Lights	M	485	492	521	501	428	531	524	456	525
	SD	55	59	44	54	86	48	45	76	58
Meters	M	511	483	508	495	502	511	512	481	508
	SD	87	124	96	93	76	85	71	90	82
Patterns	M	511	509	516	509	481	517	520	409	527
	SD	38	66	54	45	77	62	61	159	60
Arithmetic	M	491	485	535	480	458	511	487	482	529
	SD	94	115	70	76	93	58	70	95	61
Problem Solving	M	513	493	524	482	463	520	494	467	506
	SD	30	40	45	68	65	50	33	63	48
Tracking	M	526	510	543	515	414	511	509	421	522
	SD	83	87	73	77	114	75	70	114	61
Overall	M	506	496	525	497	452	519	508	453	519
	SD	40	51	31	34	59	33	29	64	27

any significant effects during the morning (hangover) sessions was not influenced by the highly significant effects at midnight, separate analyses were conducted using evening-morning difference scores, and morning-only performance scores; no significant differences were obtained among the conditions by either of these analyses. Moreover, morning scores for each alcohol condition were numerically better than predrinking scores.

Ratings of Effort and Performance. Ratings by subjects of their effort and performance for individual MTPB tasks and the mean overall performance ratings are presented in Table 5. Analyses of variance yielded only two significant effects for effort and one for performance ($p < .05$ for each). In all cases they were sessions effects: two for warning lights and one for meters. Individual comparisons for the warning lights and the meters effort ratings indicated that the vodka condition yielded lower ratings at midnight compared to predrinking ratings ($p < .05$ in both cases); a similar (but smaller) difference occurred for each of the other individual tasks in the

TABLE 5. Means and standard deviations for ratings by the subjects of the effort they expended (1-5 scale) and the quality of their performance (1-5 scale) on the individual tasks of the MTPB. The overall rating is a mean of the individual ratings.

Rating Condition		Placebo Pre	Placebo PI	Placebo PII	Bourbon Pre	Bourbon PI	Bourbon PII	Vodka Pre	Vodka PI	Vodka PII
Effort										
Lights:	M	4.9	4.6	4.7	4.6	4.6	4.6	4.8	4.3	4.6
	SD	0.3	0.7	0.5	0.5	0.7	0.7	0.4	0.8	0.7
Meters:	M	4.5	4.3	4.5	4.2	4.4	4.2	4.6	3.7	4.1
	SD	0.8	0.9	0.8	0.9	0.7	0.6	0.7	1.2	0.9
Patterns:	M	4.7	4.6	4.6	4.4	4.6	4.5	4.6	4.3	4.6
	SD	0.7	0.7	0.7	1.0	0.7	0.7	0.7	0.9	0.8
Arithmetic:	M	4.7	4.3	4.6	4.3	4.6	4.5	4.6	4.3	4.6
	SD	0.7	0.9	0.9	1.3	0.7	0.7	0.9	0.8	0.8
Problem: Solving	M	4.7	4.3	4.6	4.4	4.6	4.5	4.6	4.3	4.6
	SD	0.7	1.0	0.9	1.0	0.7	0.7	0.7	0.8	0.7
Tracking:	M	4.6	4.2	4.6	4.2	4.5	4.4	4.6	4.1	4.5
	SD	0.7	1.0	0.7	1.3	0.7	0.7	0.9	0.9	0.9
Overall:	M	4.7	4.4	4.6	4.3	4.5	4.4	4.6	4.2	4.5
	SD	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.2
Performance										
Lights:	M	3.6	3.6	3.8	3.7	3.4	4.0	3.6	3.2	3.7
	SD	0.8	1.1	0.8	0.7	0.9	0.8	0.8	0.9	0.7
Meters:	M	3.0	3.3	3.2	2.7	2.7	3.0	3.0	2.4	3.1
	SD	0.6	1.1	0.8	0.7	0.9	0.5	0.8	0.9	0.5
Patterns:	M	3.4	3.4	3.3	3.3	3.1	3.1	3.2	3.3	3.4
	SD	0.9	1.0	0.7	0.9	0.8	0.8	0.8	0.8	0.8
Arithmetic:	M	3.6	3.5	3.4	3.1	3.3	3.3	3.0	3.5	3.6
	SD	0.8	1.2	1.1	0.8	0.8	1.3	1.0	0.9	0.7
Problem: Solving	M	3.5	3.2	3.3	3.1	3.0	3.1	3.2	3.3	3.6
	SD	0.7	1.0	0.8	0.3	0.5	0.3	0.9	0.5	0.5
Tracking:	M	3.2	3.1	3.4	3.1	3.2	3.2	3.1	3.0	3.4
	SD	0.6	1.0	0.8	0.8	0.6	0.9	0.7	1.0	0.7
Overall:	M	3.4	3.3	3.4	3.2	3.1	3.3	3.2	3.1	3.4
	SD	0.2	0.2	0.2	0.3	0.2	0.4	0.2	0.4	0.2

vodka condition, but they did not reach significant levels. Warning lights performance ratings also had significant individual effects confined to the vodka condition at midnight, viz the midnight session was poorer than both the vodka morning session ($p < .05$) and the placebo midnight session ($p < .01$).

The overall composite MTPB ratings (the means of the individual task ratings) yielded no significant effects for either effort or performance. The performance ratings did show more consistency than those for effort in that midnight ratings were lowest for all three treatments and morning ratings were highest, but the differences were slight. The pattern of these performance ratings, while not statistically significant, agreed generally with the actual performance results in that poorest scores by both types of measures occurred at midnight and the highest scores occurred during the morning sessions for each condition.

Speech Comprehension.

Mean scores for the speech comprehension test are presented in Table 6. Interestingly, they show no effects of the alcohol treatment. Scores were

TABLE 6. Means and standard deviations for the percentages of single words correctly identified against a background of aircraft engine noise.

	Control			Placebo			Bourbon			Vodka		
	Pre	PI	PII	Pre	PI	PII	Pre	PI	PII	Pre	PI	PII
M	60.9	-	53.9	61.3	56.9	53.6	59.5	57.4	53.1	60.2	58.3	54.4
SD	3.7	-	6.3	3.4	8.6	5.6	6.3	7.0	6.9	7.5	8.1	6.5

remarkably consistent for like sessions across conditions and showed identical patterns within conditions, viz scores were best in the evening and poorest in the morning. An overall analysis of variance yielded only one significant effect ($p < .001$); that was for sessions. Individual comparisons yielded only two significant differences; morning scores for the placebo ($p < .01$) and bourbon ($p < .05$) conditions were poorer than those obtained prior to drinking.

Drunkenness and Hangover Ratings.

All subjects gave "0" scores on rating degree of drunkenness for control and placebo morning sessions; two subjects gave ratings of "1" ("slightly drunk") during the placebo midnight sessions (see Table 7). All subjects indicated drunkenness at midnight during bourbon and vodka sessions (mean ratings of 2.36 and 2.09, respectively) and one subject each gave a "1" rating during the morning sessions for the two alcoholic beverages. Analyses of variance yielded highly significant effects ($p < .001$ in all cases) for

TABLE 7. Means and standard deviations for single-item ratings by the subjects of their degree of drunkenness (0-3 scale) and degree of hangover (0-4 scale) and for their overall score on the hangover questionnaire.

Measure		Control PI	Control PII	Placebo PI	Placebo PII	Bourbon PI	Bourbon PII	Vodka PI	Vodka PII
Drunkenness	M	-	0.0	0.2	0.0	2.4	0.1	2.1	0.1
Rating	SD	-	0.0	0.4	0.0	0.9	0.3	1.3	0.3
Hangover	M	0.0	0.1	0.0	0.1	0.7	1.4	0.2	1.4
Rating	SD	0.0	0.3	0.0	0.3	1.3	0.8	0.4	1.2
Hangover	M	2.6	2.5	4.0	5.7	10.1	12.6	7.7	14.0
Score	SD	2.7	3.1	3.4	5.2	11.9	4.9	9.8	9.7

sessions, conditions, and the interaction term. The differences were accounted for by the significant midnight ratings following bourbon and vodka. Specifically, the midnight session for both alcoholic beverages had significantly higher ratings than the respective predrinking and morning sessions and also had higher ratings than the placebo midnight session ($p < .001$ for every comparison).

Since some of the items on the Hangover Questionnaire related to effects associated with some sleep loss, control and placebo sessions differed; hence, all four conditions were included in an overall analysis of variance. Mean scores for each condition appear in Table 7. Control session scores were lowest, placebo scores were intermediate, and the two alcoholic beverages yielded the highest scores. The overall analyses of variance yielded a significant sessions effect ($p < .001$) which was accounted for largely by a significantly higher score at midnight for the bourbon condition as compared with the control condition ($p < .05$) and significantly higher scores in the morning for both bourbon ($p < .01$) and vodka ($p < .001$) than for control; vodka morning scores were also higher than vodka midnight scores ($p < .05$) and higher than placebo morning scores ($p < .05$). Although not all individual comparisons were significant, scores for the placebo condition clearly fell between those of control and alcohol, probably reflecting some effects of sleep loss. Bourbon scores were worst at midnight and vodka scores were the poorest for the morning sessions. Thus, strong hangover symptoms occurred for both types of alcoholic beverages, but performance on the various tasks was not significantly affected.

Anxiety and Mood.

The mean trait score for the group on the STAI was 29.09 which is a lower mean anxiety score than that obtained for college undergraduates (45). With regard to state scores, since control scores differed from placebo ($p < .05$), all four conditions were included in the overall analysis. Mean scores for each condition appear in Table 8. The highest scores were obtained on the mornings following the ingestion of alcohol. The overall analysis of variance yielded significant F ratios for sessions and conditions ($p < .05$ in both cases). Simple effects and HSD tests indicated that morning scores for both bourbon ($p < .05$) and vodka ($p < .001$) differed from the control condition and vodka also differed ($p < .05$) from placebo. Vodka morning scores were also higher than both the predrinking and midnight sessions. Placebo morning scores fell between those of the control and alcohol conditions and probably reflect some effect of sleep loss. Thus, the highest anxiety scores were obtained the morning after ingestion of alcohol and there was no bourbon vs. vodka difference although scores for the vodka condition were numerically greater.

Mood scores for the five factors assessed are presented in Table 8. Control and placebo conditions had the poorest scores at midnight for fatigue, vigor, and sleepy; nonchalance and affect tone scores were not as consistent. The two alcohol conditions also yielded poor scores for fatigue, vigor, and sleepy at midnight, but the poorest scores for these and the other two factors were recorded in the morning during hangover periods. Analyses of variance for the separate factors yielded the following significant results: for fatigue, sessions ($p < .001$) and treatment ($p < .05$) effects; for nonchalance, sessions ($p < .01$) and interaction ($p < .01$) effects; for vigor, sessions ($p < .001$) and interaction ($p < .05$) effects; and for sleepy and for affect tone, sessions effects ($p < .001$ and $p < .05$, respectively).

Simple effects and HSD tests yielded the following significant results: (a) for placebo, midnight scores for fatigue and sleepy were both higher ($p < .05$) than their respective predrinking scores; (b) for bourbon, both midnight and morning scores were higher than predrinking scores for fatigue and sleepy ($p < .001$ in all cases) and for vigor ($p < .05$ and $p < .001$ for midnight and morning, respectively), while nonchalance scores at midnight were higher than both the predrinking ($p < .01$) and morning scores ($p < .001$); (c) for vodka, the morning session was worse than the predrinking session for fatigue ($p < .001$), sleepy ($p < .01$), and vigor ($p < .01$), and for vigor, the morning score also differed from the midnight score ($p < .01$). With respect to group differences, the morning ratings for fatigue and vigor were significantly poorer for the bourbon ($p < .01$ and $p < .05$, respectively) and the vodka conditions ($p < .05$ and $p < .01$, respectively) when compared to placebo. Also, the midnight score for nonchalance was higher for the bourbon condition than for either placebo ($p < .001$) or vodka ($p < .01$). Thus, the highest scores for fatigue and sleepy and the lowest scores for vigor were obtained on the mornings after alcohol ingestion and there were no differences between bourbon and vodka conditions.

TABLE 8. Means and standard deviations for "state" scores on the State-Trait Anxiety Inventory (STAI) and for five moods assessed by the modified Mood Adjective Check List (mMACL).

Measure		Control Pre	Control PI	Control PII	Placebo Pre	Placebo PI	Placebo PII	Bourbon Pre	Bourbon PI	Bourbon PII	Vodka Pre	Vodka PI	Vodka PII
STAI													
STATE	M	27.4	30.0	27.6	30.2	29.6	29.8	28.7	29.8	32.7	29.6	29.5	34.6
	SD	3.9	4.2	4.0	6.4	4.9	6.1	8.1	6.0	3.9	8.1	6.5	6.1
mMACL													
Fatigue	M	26.4	44.4	23.2	21.9	33.4	30.7	21.5	41.9	45.1	26.1	35.5	44.6
	SD	17.5	14.0	9.9	8.3	14.4	16.3	9.5	15.4	12.6	6.6	9.5	12.1
Nonchalance	M	9.8	11.0	8.1	10.2	9.8	9.4	10.2	14.1	9.5	11.7	10.3	9.3
	SD	4.1	3.0	2.2	2.9	3.8	2.8	2.9	3.0	1.5	3.2	2.0	2.1
Vigor	M	17.8	12.0	17.7	18.4	14.8	15.2	18.6	13.0	9.6	16.3	16.2	9.0
	SD	6.4	3.9	4.3	3.3	4.6	5.2	5.4	5.9	5.8	3.6	6.3	4.3
Sleepy	M	13.3	24.2	11.4	11.4	19.9	18.1	11.3	23.8	24.6	13.8	20.2	24.6
	SD	9.4	7.8	5.2	5.1	8.1	10.2	7.6	10.6	7.8	4.1	6.5	7.7
Affect Tone	M	8.6	8.3	8.3	8.6	7.6	7.7	9.7	8.4	7.8	8.6	9.4	7.6
	SD	1.4	2.2	1.9	1.6	1.5	2.1	2.5	3.5	2.2	1.5	3.3	2.3

Sex Differences.

Analyses of variance (unweighted means solution) for groups of unequal size were performed for the various scores derived during the study for the seven men and four women (51). Although the men tended to have numerically better scores on some measures (e.g., tracking and STAI) and the women tended to perform better on other measures (e.g., speech perception), there were no significant sex differences overall and no differential effect of alcohol attributable to sex for this small-sample comparison.

Effects of Smoking.

Six of the subjects were nonsmokers; the remaining five smoked cigarettes ad lib during the study. Analyses of variance on the various measures yielded no statistically significant overall differences and no differential effects of alcohol between these small samples of smokers and nonsmokers.

Discussion.

The present study demonstrated significant impairment during acute intoxication for almost all tracking and MTPB measures. The only performance test not affected by alcohol was that of speech comprehension. During sessions conducted the "morning after," small circadian effects were consistently evident (albeit generally insignificant statistically) on all tasks, but there were no significant impairments due to alcohol and no congener vs. noncongener differences. While subjects reported significant hangover symptoms, increased anxiety, greater fatigue, and less vigor, there were no statistical differences between the effects of bourbon and vodka on any of these ratings (in fact, vodka, the noncongener beverage, produced numerically higher mean overall hangover and anxiety scores than did bourbon).

In this study, mean peak blood alcohol levels were reasonably high (93 mg percent by breathalyzer) and subjects underwent some sleep deprivation. The tests sampled intensive tracking behavior in a simulated nighttime situation, included angular motion effects, and also measured "long term" (1 hour) time-sharing behavior. And, while results showed the tests to be moderately sensitive to circadian rhythms and clearly sensitive to acute alcohol effects (with the exception of speech comprehension), none showed hangover effects.

The results on speech comprehension are of some interest. Studies of alcohol effects in the areas of audition and speech perception are extremely few (48,49). It appears that alcohol depresses the acoustic reflex (39) and the auditory evoked (cortical) response (17) with the latter remaining depressed during hangover periods (24). While Schwab and Ey (41) reported no acute effects of alcohol on auditory sensitivity, Schneider and Carpenter (40) obtained small deficits in detecting a signal against a background of noise. Of more direct relevance to present results, however, are the findings of Bablik (3) who reported BALs between 32 and 195 mg percent and obtained no detrimental effects of alcohol on hearing threshold or auditory fatigue. However, he reported reduced comprehension both of numbers (up to 35 dB) and of words (up to 70 dB) when BALs exceeded 100 mg percent. No detrimental effects on speech comprehension were obtained from subjects whose BALs were below 100 mg percent. This latter result agrees with our data and suggests that subjects in the present study might have suffered some impairment of speech perception had their BALs been higher.

A second interesting feature of the speech comprehension data is the circadian effect, which runs opposite to that suggested by the performance measures. Specifically, performance scores for the various tasks were all better in the morning than they had been the previous evening, but speech perception was poorest in the morning (significantly so for the bourbon and placebo conditions).

We obtained no general or differential effects of alcohol on performance or on hangover symptoms that could be related to either sex or the smoking of cigarettes.

While the results obtained in this study do not contradict the "8-hour rule," they should be interpreted with caution. Our subjects were exceptionally well motivated and interested in the outcome; they were also routinely encouraged to do their best prior to each task. From an aviation point of view, additional stressors, such as noise and altitude, were not present. Moreover, a significant hangover effect was obtained in the sense that two subjects, on one occasion each, declined to perform the tracking task during angular motion due to their concerns about nausea.

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